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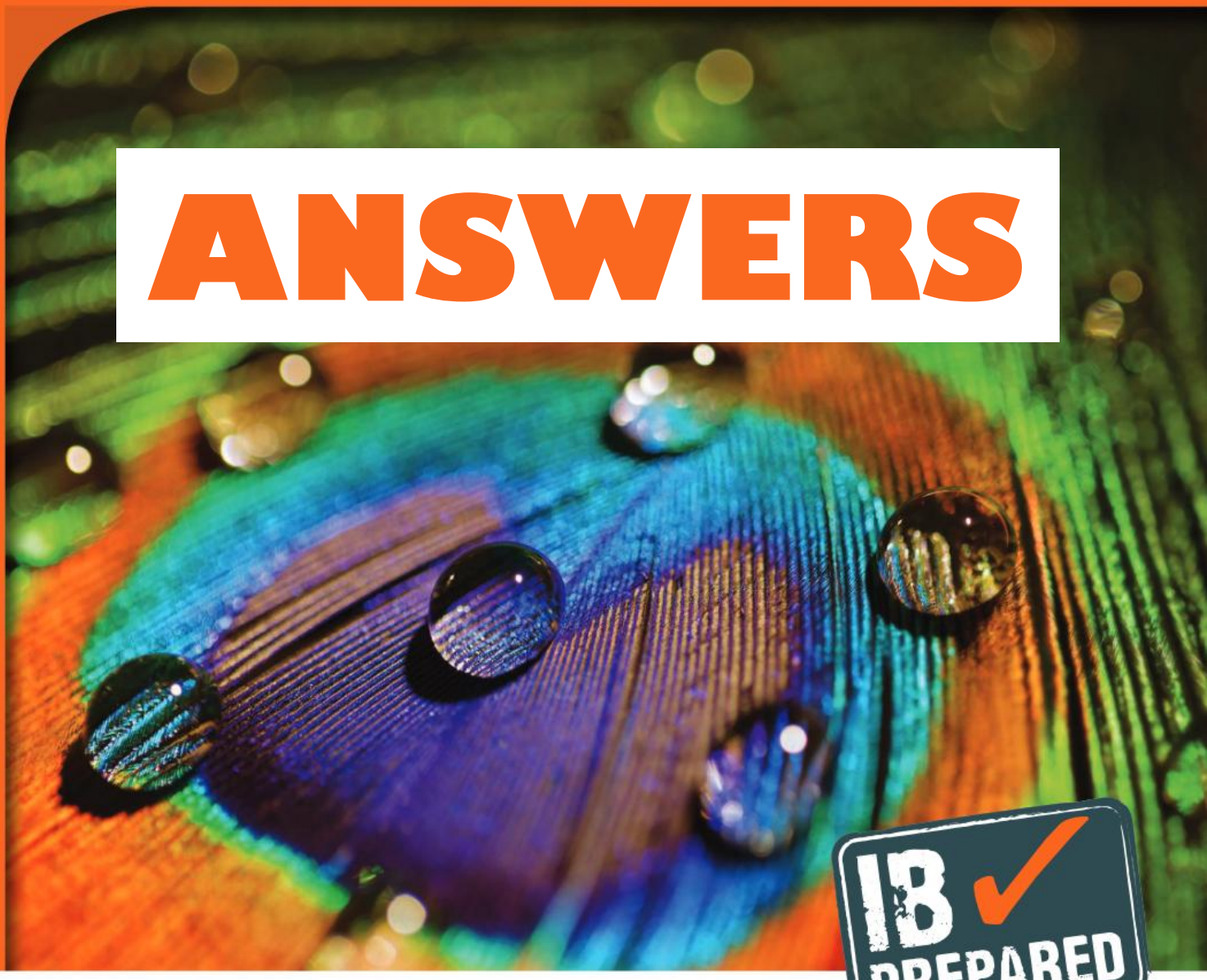
BIOLOGY



ANSWERS

IB PREPARED

IB DIPLOMA PROGRAMME

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IB Prepared Biology

Answers to practice problems

Here are the answers to the practice problems from *IB Prepared Biology*.

For direct access, click on the name of the chapter.

1 Cell biology

1. These cells have many mitochondria for active transport. The function of the mitochondria is the production of energy or ATP through aerobic respiration. The cells also have microvilli to increase the surface area to volume ratio of the cells for absorption of food.

2. Glucose diffuses across membranes through facilitated diffusion, down the concentration gradient. The carrier proteins at the membrane alter their shape after binding to the glucose molecules and so transport the glucose from one side of the membrane to the other.

3. a) Danielli's observations on the surface tension of lipid bilayers, the rate of penetration of different cells by the same substance, and the rate of entry of the same cell by different substances, together with the images obtained from electron microscopy led Davson and Danielli to propose the "lipo-protein sandwich" model, as the lighter lipid layer seemed to be sandwiched between two darker protein layers.

   Davson–Danielli's model was falsified when experiments showed that the membrane proteins were not soluble, therefore could not be in the layer next to water. Freeze-fracture microscopy was used to split open the membrane and revealed irregular rough surfaces within the membrane, which therefore could not be a constant layer. Fluorescent antibody tagging of membrane proteins showed they were mobile and not fixed in place, confirming the fluid mosaic structure.

   b) Endocytosis is the bulk transport of nutrients or materials into a cell. The fluidity of the plasma membrane allows part of the membrane to surround the material, enclosing it to form a vesicle.

4. Miller and Urey simulated the conditions of pre-biotic Earth in a closed container. It contained water vapour, a mixture of ammonia, methane and hydrogen. This produced a reducing atmosphere. They added sparks that gave an electric discharge to simulate lightning. They then cooled the mixture in a condenser. They obtained amino acids, which are organic compounds, from inorganic compounds.

5. Mitosis is the division of a nucleus to produce two genetically identical daughter nuclei. It consists of four phases: prophase, metaphase, anaphase and telophase. Interphase is the metabolically active phase between cell divisions. Interphase consists of the S phase, G1 and G2. DNA replicates in the S phase and duplication of organelles occurs in G1 and G2. Cytokinesis occurs after mitosis, where the cell divides into two cells to hold one nucleus each.

2 Molecular biology

1. Humans cool down by sweating. The evaporation of water as sweat requires an input of energy. Due to the high specific heat capacity of water, a lot of thermal energy needs to be absorbed before sweat can evaporate. This energy comes from the surface of the skin, where the blood has transported heat through capillaries.

2. Enzymes catalyse or speed up biological reactions. They lower the activation energy of a chemical reaction, increasing the likelihood of the reaction happening. The substrate binds to the active site, forming an enzyme–substrate complex. Enzymes are substrate-specific.

3. Place egg white in different test tubes. Prepare 6 water baths at different temperatures, ranging from 0°C to 100°C. Control the temperature of the water baths with a thermometer. Place the test tubes into the water baths and record the time it takes for the egg white to lose its clarity. Variables that might affect the reaction, such as pH, must be kept constant throughout the experiment.

4. Light is absorbed by chlorophyll in the light-dependent stage. Chlorophyll absorbs more red and blue light than green light. The absorbed light energy is converted to chemical energy by the production of ATP. Light also splits water molecules by photolysis, which produces oxygen as a waste product together with hydrogen in the form of NADPH (reduced NADP). In the light-independent stage, plants absorb or fix carbon dioxide from the air (or water in aquatic plants) and use the ATP and NADPH from the light-dependent stage to produce carbohydrates such as starch.

3 Genetics

1. Cells are grown with radioactive thymidine, which is incorporated into the DNA during replication. Radioactively labelled DNA from broken cells is spread on a glass slide and all the molecules are covered with a light-sensitive emulsion containing silver bromide. The radiation emitted by the radioactive thymidine transforms silver bromide into insoluble silver grains. The tracks of silver grains resulting from exposure of DNA to radioactive thymidine allow measurements of the DNA fibres.

2. **a)** **i)** Co-dominant: both alleles being expressed in the phenotype of the individual.
Recessive allele: an allele that produces its characteristic phenotype only when homozygous / when its paired allele is identical.

ii) Locus: the position of a gene on a chromosome.
Sex linkage: the phenotypic expression of an allele related to the sex chromosomes.

b) Blood group is inherited by multiple alleles. A and B are co-dominant while O is recessive. I^A is the allele for group A, I^B is the allele for group B, i is the allele for group O. $I^A I^A$ and I^A i are genotypes for group A, $I^B I^B$ and I^B i are genotypes for group B, ii is the genotype for group O and $I^A I^B$ is the genotype for group AB. If two people with the same blood group in the homozygous state have a child, the child will have the same blood group as the parents. If the mother has blood group A and the father B and both are homozygous, all the children will have the blood group AB.
There are several crosses that can be done to show the inheritance of blood groups.

If the mother is A heterozygous and the father O:

	I^A	**i**
i	I^A i	i i
i	I^A i	i i

There is a 50% chance of a child being blood group A and 50% O.

Note: more crossings can be shown for a mark.

3. Oocytes are enucleated by aspiration using a pipette. After enucleation, all oocytes are immediately reconstructed. Donor cell injection is conducted in the same medium used for oocyte enucleation. One donor cell is placed between the zona pellucida and the ooplasmic membrane using a glass pipette. The cell and oocyte are incubated together and electrofused. The nuclear transfer embryos are grown on primary oviduct epithelial cells and later transferred to a recipient, where pregnancy will occur.

4. Meiosis explains the movement of Mendel's particles. Meiosis has two divisions where the cells go from diploid to haploid. The law of segregation states that of one pair of alleles, one allele enters one gamete and the other allele enters the other gamete. In meiosis, the homologous chromosome pairs line up on the equator in metaphase I. Homologues separate during anaphase I, one to each opposite pole. The law of independent assortment says that in the segregation of alleles, one gene is independent of the segregation of the alleles of another gene. This is because the homologues of one of the chromosome pair line up independently of homologues of other chromosomes at metaphase I. Homologues separate randomly at anaphase I, therefore haploid cells have a random assortment of homologues.

4 Ecology

1. Worms are primary consumers. Energy (80–90%) is lost between the producers and primary consumers. The loss is as heat from respiration used to produce energy. There is also loss through egestion of indigestible molecules such as cellulose. Therefore, worms are less valuable as a food source than primary producers. Another problem is that worms neither taste that good nor are appealing, so might not be a very popular source of food.

2. **a)** Methane is produced from organic matter in anaerobic conditions by archaeans. Methanogenic archaeans produce methane from carbon dioxide and hydrogen. Methanogenic archaeans can also transform acetate into carbon dioxide and hydrogen, which they then turn into methane. Some methane diffuses into the atmosphere or accumulates in the ground.

b) Carbon dioxide causes much less warming per molecule than methane, but as it is at a much higher concentration in the atmosphere its impact on global warming is higher.

3. CO_2 is produced from respiration in organisms, and by the combustion of biomass or fossil fuels. CH_4 is produced by anaerobic respiration of biomass by methanogenic archaeans. CH_4 is oxidized to CO_2 and water by combustion. In anabolic reactions, CO_2 is converted into carbohydrates or organic compounds by autotrophs (producers) by photosynthesis. In marine ecosystems, CO_2 can be converted to calcium carbonate by fossilization into limestone. In waterlogged soils or acidic environments, partially decomposed organic matter or biomass can be converted into peat. Through fossilization, coal, oil, gas or other fossil fuels are formed. CO_2 and CH_4 are both greenhouse gases, increasing the greenhouse effect. Both absorb long-wave radiation from the earth and retain the heat in the atmosphere. Increased CO_2 concentrations in the atmosphere correlate with increased combustion of fossil fuels. Rising average global temperatures correlate with more greenhouse gases in the atmosphere. Cattle production, rice paddies and defrosting of tundra increase CH_4 in the atmosphere. Increasing concentrations of CO_2 lead to acidification of marine or aquatic environments. The global temperature increase influences climate patterns.

5 Evolution and biodiversity

1. **a)** 0.95
Note that ratios do not have units.

b) *G. scandens* has a sharp beak while *G. magnirostris* has a large blunt shape. The ratio length to depth in *G. scandens* is greater because their beak is longer than it is wider; while in *G. magnirostris* it is wider than it is long, therefore the ratio is smaller than 1.

c) Those with long beaks are able to punch holes in the cactus fruit and eat the fleshy pulp which surrounds the seeds, whereas those with shorter beaks tear apart the cactus base and eat the pulp and any insect larvae and pupae (both groups eat flowers and buds). This dimorphism clearly maximizes their feeding opportunities during the non-breeding season when food is scarce. Because of the strong beak in *G. magnirostris* we could believe they feed on large seeds of cacti.

d) Natural selection acts differently on the two populations, so they will evolve in different ways. The feeding habits of the two populations will make them gradually diverge. After a time they will be recognizably different. If the populations subsequently merge and have the chance of interbreeding, but do not actually interbreed, it would be clear that they have evolved into separate species, by speciation.

2. Evolution is a cumulative change in allele frequency of the population over time. This change is due to natural selection. A population has variations amongst the individuals. These variations arise by meiosis or through sexual reproduction. Although many mutations are neutral, mutations are also a source of variation. Certain variations give an advantage to some organisms over others in certain environments. Populations (or species) produce more offspring than the environment can support. Individuals of the species compete for the same resources. The better-adapted organisms tend to survive and reproduce and the less-well-adapted organisms tend to die or reproduce fewer offspring. Individuals that reproduce pass on their alleles to their offspring. Natural selection increases the frequency of alleles of the better-adapted organisms.

3.

Feature	**Phylum**					
	Porifera	**Cnidaria**	**Platyhelminthes**	**Annelida**	**Mollusca**	**Arthropoda**
Articulated legs						✓
Bilateral symmetry			✓	✓	✓	✓
Outer shell					✓	

4. **a)** A: presence of gills or fins or scales or no limbs or external fertilization will have separated fish from the rest of the animals.
B: homeothermic or endothermic or warm-blooded or lungs or tetrapod or four limbs or pentadactyl limbs or internal fertilization will have signified the appearance of birds and mammals.
C: hair or fur or mammary glands or milk distinguishes mammals.

b) Eukaryotes

6 Human physiology

1. **a)** Dialysis tube resembles the lining of the intestine, as it is selectively permeable or partially permeable, allowing some substances through and not others.

b) 7 mg dm^{-3}

c) **i)** Amylase is an enzyme that digests starch into maltose. Maltose can pass through the dialysis tube into the water outside the tube. There, the maltase enzyme digests it into glucose molecules.

ii) Glucose, produced by the digestion of maltose by maltase outside the dialysis tube, diffuses back into the dialysis tube. Only a few molecules of glucose can be formed from the digestion by amylase.

2. **a)** William Harvey stopped the blood from circulating through veins in the arm using the pressure of his fingers. He noticed that the flow was unidirectional, showing the fact that valves avoid backflow in veins. When he tied an artery, the blood accumulated close to the heart, while when he tied a vein, the blood accumulated further away from the heart. He also calculated the amount of blood the heart pumps in one hour is equivalent to three times the weight of a person. This confirmed that blood needs to re-circulate to and from the heart, and not be formed constantly in the liver as it had been previously believed.

b) Double circulation of blood means that blood passes twice through the heart on each circulation of the body. It passes through the left part of the heart once to send blood to all the tissues in the systemic circulation. And the second time, in the pulmonary circulation, it passes through the heart to be sent to the lungs to receive oxygen. In the systemic circulation, blood enters from the pulmonary veins into the left atrium or auricle. The atrioventricular valves open allowing blood to flow into the left ventricle. During the systole, the atrioventricular valves close and the left ventricle contracts. The semilunar valves open allowing blood to flow out of the aorta. Once blood passes through the tissues it returns to the heart for the pulmonary circulation. It enters the right atrium through the vena cava. It passes through to the right ventricle that pumps it out through the pulmonary arteries to the lungs.

3. **a)** **i)** Smokers = 66 years
Non-smokers = 76 years

$$\frac{76 - 66}{76} \times 100 = 13\%$$

ii) Non-smokers have a life expectancy of 76 years, while smokers have a life expectancy of 66 years. The data shows that non-smokers have 10 years more life expectancy than smokers, who have a 13% shorter life expectancy, therefore supporting the hypothesis.

b) The lungs are actively ventilated to ensure that gas exchange can occur passively. Air enters the lungs through the nose, trachea, bronchus, bronchioles that lead to the alveoli. Ventilation of air and the blood circulation maintain concentration gradients of oxygen and carbon dioxide between air in the alveoli and the blood flowing in adjacent capillaries. Gaseous exchange occurs in the alveoli. The wall of an alveolus is formed by one layer of epithelial cells called pneumocytes. The type I pneumocytes are extremely thin alveolar cells that are adapted to carry out gas exchange. Type II pneumocytes secrete a solution containing surfactant that creates a moist surface inside the alveoli to prevent the sides of the alveolus adhering to each other by reducing surface tension. Oxygen from the air diffuses into the blood capillaries that are branches of the pulmonary artery. The red blood cells or erythrocytes in these capillaries take up the oxygen joining the hemoglobin. Carbon dioxide diffuses out of the capillaries into the air sacs of the alveoli to be eliminated when breathing out.

c) Lung cancer and emphysema are diseases of the lungs causing damage to the epithelial tissues, causing a decrease in gaseous exchange. This causes shortness in breath and fatigue. Both can lead to death. For example, in Argentina, in 2016, there were nearly 40,000 deaths related to tobacco in people over 35 years old. The cost of these premature deaths is around 500 million pesos, which represents around 0.15% of the gross domestic product. The cost of treating these diseases is also very high. In many cases they require a lung transplant.

4. **a)** **i)** 7 rats **ii)** 3 ng kg^{-1} day^{-1}

b) The data supports the hypothesis, as there is no atrophy without botulin and there is atrophy with botulin. The amount of rats presenting atrophy increases as the dose increases.

c) The body mass of rats without botulin (control rats) increases as days go by, while the body mass of rats treated with botulin decreases till day 5 after injection, stays constant, and then after 10 days starts to increase. After 20 days the body mass of control rats has increased from 360 g to 425 g while in rats treated with botulin the body mass shows an overall increase from 360 g to 370 g. The body mass of control rats is always higher than treated rats even if they started with the same mass.

d) The data shows that botulin affects the rats' muscle by producing atrophy and it reduces the body mass increase. The dose used will determine the effect on rats, as higher doses have more effect than low doses. The effect might be reduced with time, as 20 days after injection the body mass seems to be increasing once more.

5. A neurotransmitter attaches to the receptor of a sensory neuron or on the receptor protein of the membrane of the postsynaptic motor or relay neuron, initiating transmission. Nerve impulses are action potentials propagated along the axons of neurons.
The resting potential is more negative inside (−70 mV) and more positive outside the membrane due to a greater concentration of Na^+ ions outside than K^+ ions inside the axon. Voltage gated channels open and Na^+ ions diffuse in, causing depolarization of the membrane (from −70 mV to +40 mV). Local currents affect adjacent channels, causing an action potential to be transmitted along the membrane. Depolarization is followed by repolarization of the neuron. Voltage gated channels open and K^+ ions diffuse out, repolarizing the membrane. Na-K pumps restore the Na/K balance, returning to the resting potential. Myelin around the neuron insulates the axon and speeds the transmission, as it permits saltatory conduction from node to node.

7 Nucleotides (AHL)

1. Dideoxyribonucleotides are used in the sequencing method devised by Frederick Sanger. A single-stranded DNA is used as a template. Different nucleotides are modified into dideoxyribonucleotides and used together with normal deoxyribonucleotides to replicate DNA. Because dideoxyribonucleotides lack the hydroxyl group at the 3′ end, the elongation of the DNA strand by DNA polymerase is interrupted, producing a shorter DNA chain. In four different reactions, all deoxyribonucleotides are added but in each case one of the nucleotides is replaced by a dideoxyribonucleotide with a dye in a very low concentration, allowing fragments of different sizes of DNA to be formed. The double-stranded DNA formed is denatured by heat and run in an electrophoresis. The gel will have fragments of DNA of different sizes, always containing the dideoxyribonucleotide at the 3′ end. The complementary DNA sequence (in the 5′–3′ direction) is read from the gel starting from the smallest fragment (bottom of the gel) to the largest.

2. **a)** **i)** At 4 years old both twins have 47% acetylation of histones, but at 40 years old, one twin has nearly 50% while the other has 62%.

ii) Acetylation of histones is done by histone acetyltransferase enzyme and changes the structure of the nucleosome. Acetylation removes the positive charge on the histones, thereby decreasing the interaction of the N termini of histones with the negatively charged phosphate groups of DNA. As a consequence, the condensed chromatin is transformed into a more relaxed structure that is associated with greater levels of gene transcription.

b) **i)** Methylation patterns depend on environmental factors such as hormones, drugs, and lifestyle such as feeding and exercise. When the twins were small they probably lived together and were exposed to similar environmental factors. As they grew, the factors changed.

ii) DNA methylation usually occurs on the cytosine in CpG islands or sites by DNA methyltransferase. There is an inverse relationship between CpG methylation and transcription.

3. The nucleotide sequence on the DNA determines the sequence of the mRNA that is produced by transcription. This mRNA will undergo post-transcription changes where sequences are lost as introns by splicing. Nevertheless, the exons have also been determined by the original DNA. The mRNA will enter the ribosomes and be used in translation. Initiation of translation starts with the binding of met-tRNA to the start codon. The large subunit of the ribosome binds with the starting tRNA in the P site. A binding site holds the tRNA with the next amino acid to be added. A peptide bond is formed between the amino acid at the A site and the polypeptide at the P site. The E binding site or exit is where the tRNA from the P site, now without an amino acid, leaves the ribosome. The mRNA carries a sequence of codons, each codon corresponding to 3 nucleotides; each codon will attach to an anticodon carried on the tRNA. At the same time, each tRNA is specific for a determined amino acid. This means that the sequence of codons on the mRNA will determine the order of sequence of amino acids joined by peptide bonds, determining the primary structure of the protein.

8 Metabolism, cell respiration and photosynthesis (AHL)

1. **a)** only maltose = 400 micromol min^{-1} g^{-1}
both = 150 micromol min^{-1} g^{-1}
difference = −250 micromol min^{-1} g^{-1}

400 micromol min^{-1} g^{-1} _ 100%
−250 micromol min^{-1} g^{-1} X = −250 × 100/400 = −62.5%

Answer = 62.5% reduction (or −62.5%)

b) α-glucosidase has a high activity when incubated with maltose. The activity increases at a decreasing rate, as glucose is being produced. The enzyme α-glucosidase is inhibited by negative feedback by the product of the digestion of maltose to glucose. When the bacteria were grown in a medium with glucose there was no activity. Glucose either joins the enzyme in an allosteric site of the enzyme if it is a non-competitive inhibitor or in the active site if it is a competitive inhibitor.

c) Diabetes is high levels of glucose in blood. This inhibition lowers the rate of glucose absorption through delayed carbohydrate digestion and extended digestion time. Acarbose may be able to prevent the development of diabetic symptoms. Nevertheless, enzymes in the digestive system might be digested by proteases, so it might not be effective. Testing needs to be done in animals and in humans to see any side effects. Some diabetic patients may believe they can eat more carbohydrates if they are taking the drug, hindering their treatment.

2. The amount of substrate determines the rate of reaction of an enzyme; the higher the concentration, the higher the rate till it reaches a plateau because all the active sites are occupied. The temperature of the cell is also very important, as all enzymes have an optimum temperature at which they work. The further away from the optimum temperature, the slower the rate of reaction. If the temperature is too high, then the enzymes (that are proteins) will become denatured, and the rate will drop to zero. The pH of the cell is also very important. Enzymes work most efficiently at a specific pH, so any variation of it will slow the rate of reaction. This is because the isoelectric point of the enzyme changes and therefore the structure of the active site. Minerals present inside the cell can also affect the rate of reaction. Some can act as cofactors, accelerating the rate, and some might act as inhibitors. The presence of inhibitors is an important way to control the rate of reaction. A competitive inhibitor will affect the rate at low concentrations of substrate, but will have little effect at high concentrations; while a non-competitive inhibitor will always affect the rate of reaction regardless of the concentration of substrate. This is because the competitive inhibitor joins the enzyme at the active site, competing with the substrate. A non-competitive inhibitor joins the active site in an allosteric part of the enzyme, modifying the active site. As they do not compete with the substrate for the active site, the concentration of the latter makes no difference.

3. **a)** The breaking down of methanol is a metabolic pathway because it involves a series of enzyme-catalysed chemical reactions.

   b) Both decrease with time. Methanol decreases to half after 60 hours, while formic acid decreases to half after 10 hours. The methanol level decreases a lot in the first 20 hours but then starts to level off while the formic acid decreases to zero. There is still some methanol present in the blood plasma after 60 hours, while there is no more formic acid after 30 hours. The amounts are not comparable, as the units are different.

   c) The treatment with fomepizole is efficient for methanol intoxication, as the toxic metabolic product formic acid is eliminated from blood after 30 hours. Perhaps a better method could be found to reduce the level faster, as formic acid produces acidosis and therefore tissue damage.

4. **a)** Chlorophyll in chloroplasts absorbs light. There are two photosystems: photosystem I and II. The absorbing of light produces photo-activation, by which excited or high energy electrons are produced and photolysis of water occurs. The electrons are passed along a series of carriers found in the thylakoid membranes. This generates reduced NADP. By chemiosmosis, hydrogen ions are pumped across the thylakoid membrane producing ATP. The hydrogens of the water are used and the oxygen liberated.

   b) Both light and temperature can be limiting factors determining the rate-limiting step. Light affects the light dependent stage directly. At low intensities, insufficient ATP and reduced NADP are produced. This stops the Calvin cycle operating at maximum rate. As light increases so does photosynthesis until a maximum, when it plateaus. Light is not usually the main limiting factor, as temperature affects the rate of photosynthesis more. Temperature affects enzyme activity. At low temperatures enzymes are less active. At higher temperatures they reach their maximum rate, but will then be denatured if the temperature rises too high.

9 Plant biology (AHL)

1. Marram grass is a xerophyte. The rolled leaves retain much of the water vapour transpired by the leaf as this decreases the surface exposed to the environment. The rolling maintains a humid environment, thus decreasing transpiration. The stomata are sunk in pits that lie in grooves of the lower/outer epidermis. These trap humid air, closing the stomata. Hairs on the lower/outer surface reduce movement of air. Thick waxy cuticle on the upper/inner surface reduce water evaporation.

2. **a)** 7.4 mm^3 per minute.

   b) Pressure in xylem at midnight = −0.2 MPa
   Pressure in xylem at noon = −3.0 MPa
   Difference = −2.8 MPa

   c) At midnight the stomata are closed and there is little transpiration, therefore little water flow in the xylem. As the sun comes up, the leaves of the oak start photosynthesizing. This requires gaseous exchange, so the stomata open. Water is lost by transpiration, causing the transpiration pull. Water flows from an area of high pressure (soil) to an area of low pressure (leaf air gaps). The cohesion and adhesion of water molecules allows for this transport.

   d) Pressure potential in the xylem is the pressure exerted by the rigid cell wall that limits intake of water. It causes turgor pressure, making the water move up the xylem tissue. At night the pressure in the xylem is high, as the roots are loading minerals. These minerals attract water into the xylem, increasing the pressure. During the day, while transpiration is rapid, the xylem solution becomes diluted by the entering water. Water is lost by transpiration, decreasing the pressure in the xylem.

3.

Feature	Xylem vessels	Phloem sieve tubes
In vascular bundle	present	present
Cells	dead	alive
Size of cells	larger	smaller
Pits	present	absent
Type of transport	passive	active + passive
Cell walls	cellulose + lignin	cellulose
Sieve plates	absent	between cells
Nucleus	absent	present only in companion cells

4. **a)** Intact: 31.0−12.5 = 18.5 nmol g^{-1} fresh weight.

Split: 23.0−24.7 = −0.3 nmol g^{-1} fresh weight.

b) The intact shoots and split shoots without light have approximately the same auxin concentration (slightly higher in the intact). When unilateral light is applied in the intact shoot, more auxin accumulates on the left side (away from the light) than the right side that receives light. In the split shoot there is very little difference between the sides. Because the gel is intact, the auxin diffuses so the amounts are constant throughout the gel.

c) Auxin accumulates on the dark side and is lower in the lit side when the shoot is intact, but when it is split the auxin concentration is approximately the same. This suggests that normally auxin is transported across the shoot in unilateral light from the lit side to the dark side, but cannot be transported in the split shoot.

d) Drawing showing shoot bent towards the right.

5. **a)** 60%

b) **i)** As the percentage of visitors increases, the crop yield increases till it reaches a plateau at around 7%.

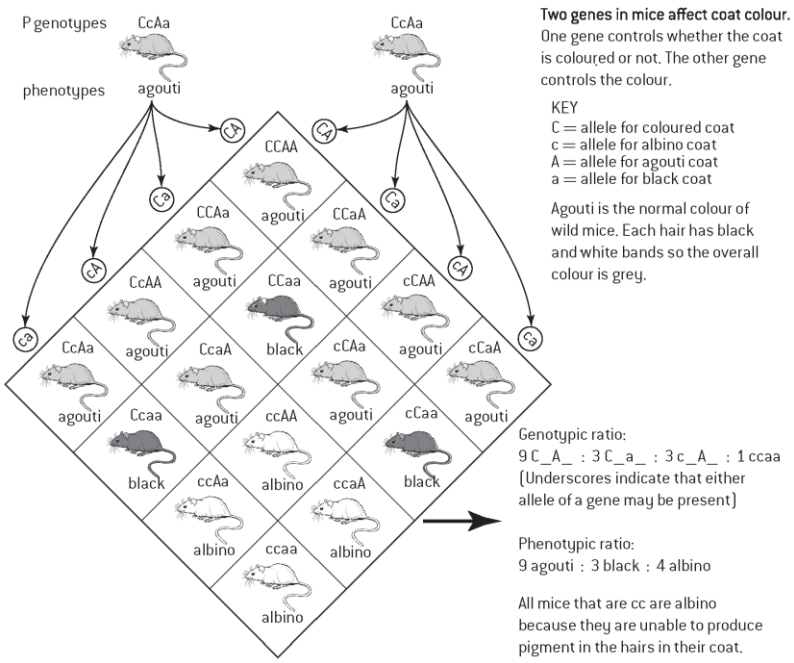
ii) The flower visitors are bees. These bees act as pollinators. They carry the male gamete in the pollen to the stigma in the flower, allowing fertilization.

10 Genetics and evolution (AHL)

1. **a)** Original chromosomes ABC and abc drawn, along with recombinants of Abc and aBC.

b) Crossing over produces different possible variants due to recombination of alleles. The further apart the alleles, the greater the chances of recombination. All these changes will produce variability. The random migration of homologous chromosomes in anaphase I and the random migration of sister chromatids (now different because of crossing over) will further produce variation.

2. a)



b) The possible phenotypes are 9 agouti; 3 black; and 4 albino.

3. A gene pool is all the genes with all their respective alleles in a population (not in a species). It can be modified as a result of geographic isolation, migration to different areas, temporal isolation or behavioral isolation. In speciation, the gene pool is split if populations are reproductively isolated so do not interbreed. In different environments there are different selection pressures as there are different niches to exploit. These changes cause natural selection. The allele frequencies change, causing the populations to diverge.

11 Animal physiology (AHL)

1. a)

Antibody				Blood group
anti O	**anti A**	**anti B**	**anti AB**	
no reaction	reaction	no reaction	reaction	**A**
no reaction	no reaction	reaction	reaction	**B**
no reaction	reaction	reaction	reaction	**AB**
no reaction	no reaction	no reaction	no reaction	**O**

b) This test needs to be performed prior to a blood transfusion, otherwise an incompatibility reaction could occur. This reaction can lead to death as blood clotting may occur throughout the body, shutting off blood supply to the main organs. There would not be enough blood reaching the brain, and not enough oxygen in tissues. The kidney and liver could be damaged.

2. **a)** The exoskeleton is the site of attachment of muscles, allowing movement as the limbs act as levers.

b) X: extensor and Y: flexor.

c) Antagonistic means that when one muscle contracts, the other relaxes. In the case of this insect, when the flexor muscle contracts the extensor muscle will relax, causing the tibia to flex. When the extensor muscle contracts and the flexor muscle relaxes, the tibia will extend.

d) The contraction of the skeletal muscle is achieved by the sliding of actin and myosin filaments. This movement requires the hydrolysis of ATP and cross-bridge formation for the filaments to slide. Calcium ions and the proteins tropomyosin and troponin control muscle contractions.

3. **a)** Maximum force in males: 50 kg
Maximum in females: 30 kg
Difference: 18 kg

b) In the graph no female forces are above 30 kg while in males they are almost always above 30 kg (with only two exceptions). This would support the hypothesis that there is a difference between males and females in maximum force exerted. However, the percentage endurance is evenly distributed for males and females all along the scale, with a large overlap in ranges. This means the hypothesis is not supported for endurance, as there is no significant difference between males and females.

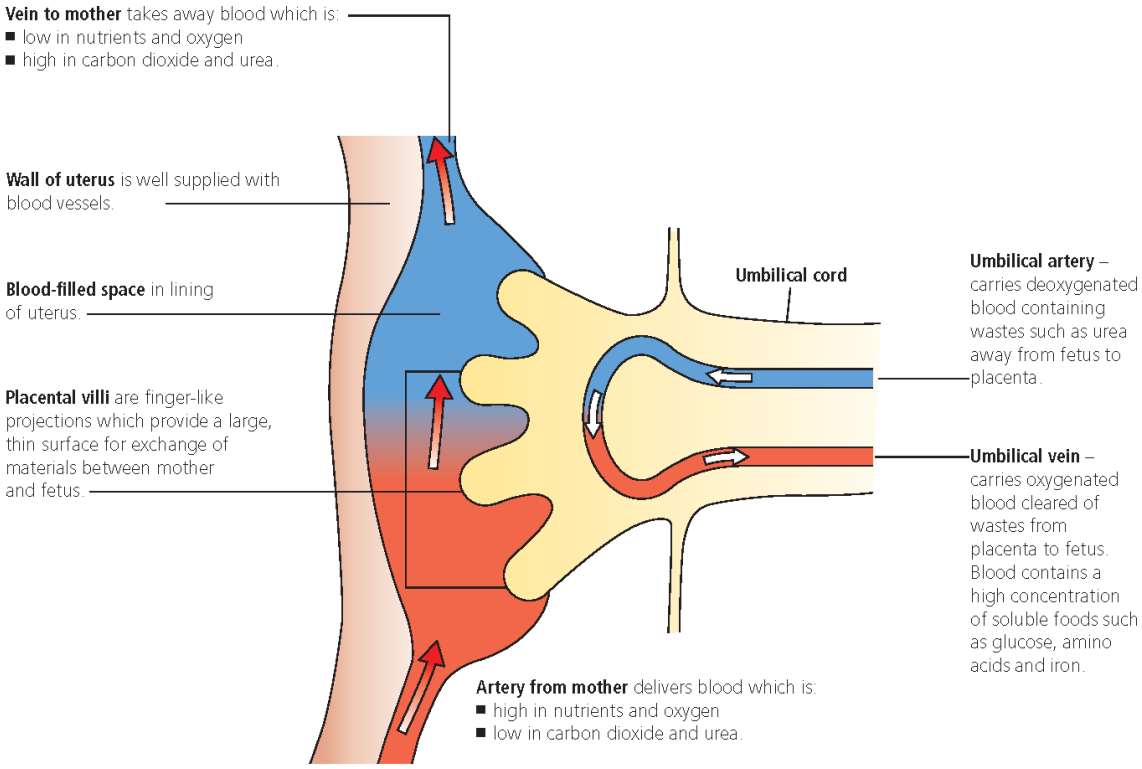
4. **a)** 180 μmol dm^{-3}

b) The higher the GFR, the lower the blood plasma creatinine concentration.

c) If renal function declines, the plasma concentration of any analyte produced in the body at a relatively constant rate and removed exclusively by glomerular filtration will increase as a reciprocal function. Therefore, a high creatinine concentration is indication of a renal problem.

5. Both the renal artery and the renal vein carry blood. The renal artery into the kidneys and the renal vein out of the kidneys, after filtration in the nephrons has occurred. The renal artery has a higher concentration of metabolic wastes such as urea, substances that are not needed in the body such as toxins, and substances that are in excess such as mineral ions, water-soluble vitamins and water. The amount of oxygen in the renal artery is higher than in the renal vein; the amount of carbon dioxide is lower.

6. The fetal blood carries carbon dioxide that passes into the maternal blood by diffusion. At the same time, oxygen passes by diffusion from the mother to the fetus. Water passes from one to the other by osmosis according to the needs of the fetus. Urea passes from the fetus to the mother by diffusion. Glucose passes from the mother to the fetus by facilitated diffusion through transport proteins. Protein is transported to the fetus as amino acids by specific amino acid transporter proteins. Some antibodies pass by endocytosis.



12 Data-based and practical questions (Section A)

1. **a)** The distance between the start and the end of the bubble is measured with a ruler. In this case it is 4 cm. The scale shows that 1 cm is equal to 0.1 μm. The real size is then calculated.

$$\text{Real size} = \frac{4\text{ cm} \times 0.1\text{ μm}}{1\text{ cm}} = 0.4\text{ μm}$$

b) Cairns grew *E. coli* bacteria in a culture medium with a radioactive DNA precursor (thymidine) for two generations. Radioactive DNA was produced by the bacteria. The bacterial cells were treated to release their DNA onto the surface of a dialysis membrane. A photographic emulsion was applied to this membrane and left in the darkness for a couple of months. The photographic film was then developed and observed under the microscope.

2. **a)** The most soluble pigment is carotene, as it moved the most in the chromatogram.

b) The R_f is the distance moved by the pigment divided by the distance moved by the solvent.

The distance moved by the solvent is 8.2 cm.

The distance covered by pheophytin is 6.5 cm.

R_f = 6.5 cm / 8.2 cm = 0.79

Remember that R_f has no units and that the value is always between 0 and 1.

c) Pigments have a given solubility in a particular solvent. If the solvent is changed, the solubility is likely to be different and so the chromatogram will be different too.

3. a) There must be light for photosynthesis to occur.

b) It is an open mesocosm because carbon dioxide is being fed into the jars.

c) The rate of photosynthesis increases at warmer temperatures, so the production of oxygen or growth of microalgae is greater.

4. There are many ways in which ventilation rate can be monitored. One is to count the breaths per minute (60 seconds). Another method is to count for a fraction and then multiply to reach the minute. For example, in 15 seconds, 3 breaths. To reach one minute you must multiply by 4. A spirometer could also be used. A spirometer is an apparatus a subject breathes through which records the flow rate of air in and out of the lungs. Another method that could be used is a data logger which records changes in chest volume. This apparatus is tied to the chest, inflated and a sensor detects the pressure due to chest inflation. (Only one method required.)

Option A Neurobiology and behaviour

1. a) The process occurring during the seven days is neurulation.

b) Axon = 350 micrometres
Dendrite = 20 micrometres
Difference = 330 micrometres.

c) The dendrites grow much less than the axon. Only one axon per neuron is formed. Chemical stimuli make one dendrite grow more and differentiate into an axon. The chemical stimulus also determines the direction the axon will take. Some axons extend beyond the neural tube to reach other parts of the body.

d) Dendrites that are not used are destroyed. This is called neural pruning.

2. a)

b) A magnetic resonance imaging (MRI) scan uses magnets and radio waves to create pictures of the body. It does not use X-rays, therefore it is safer for the body. In a functional MRI (fMRI), the parts of the brain that are active can be detected because these receive more blood flow. This can be detected by a coloured dye injected into the blood of the patient before the scan. The scan shows which parts of the brain are activated during the response to the stimulus.

3. Different colours of light are detected by photoreceptor cells called cones which are located in the retina, and concentrated in the fovea. There are three types of cone that absorb different wavelengths of visible light. A cone absorbs light and passes impulses to a bipolar cell. The bipolar cells are connected to ganglion cells. There is one-to-one connection of cones to bipolar cells and one-to-one connection of bipolar cells to ganglion cells. The impulse is relayed to the optic nerve. The right field of vision of both eyes is sent to the left part of the brain and vice versa. The information is then passed to the visual cortex in the occipital lobe of the brain.

4. Mechanoreceptors in the hand detect the roughness. Sensory neurons send impulses to a nerve which carries the information to the brain. Once in the brain, interpreting occurs in the cerebral cortex. The cerebral cortex is involved in thinking and in memory. The motor part of the cerebral cortex is involved in motor control. Motor neurons send impulses to the muscle of the arm to move the hand away.

5. a) 600 mm^3

   b) Volume of left nucleus accumbens increases in THC consumers compared to the control. There is no significant difference in the right nucleus accumbens.

   c) THC inhibits the release of neurotransmitters by blocking receptors. It is a sedative drug because it decreases post-synaptic transmission.

6. Vampire bat food sharing is potentially a powerful model for understanding the cognitive enforcement of cooperation, because this behaviour is completely natural, energetically costly, and occurs between both kin and non-kin. If bats do not receive blood within the 70 h, they will die. Because blood sharing allows more bats to survive, by natural selection the bats that have this characteristic are more fit for survival, therefore the characteristic is selected for by natural selection. This characteristic will be inherited.

Option B Biotechnology and bioinformatics

1. Biogas production refers to the digestion of various types of organic waste, food waste, plant bagasse, wastewater, sewage sludge or animal manure to make biogas. Biogas, mainly a mixture of methane and some carbon dioxide, arises from the activity of a group of anaerobic bacteria which decompose organic matter, therefore recycling organic wastes into fertilizer and providing energy. The energy contained in biomass is converted into a useful fuel which may be stored and transported. It is a method of waste treatment aimed at reducing its hazardous effects on the environment. Methanogenesis is a series of complex biochemical reactions occurring under anaerobic conditions where organic substances are decomposed into simple, chemical stable compounds. Three different types of anaerobic microorganism are involved in methanogenesis. The first group is formed by Eubacteria which convert the untreated organic waste into a mixture of organic acids, alcohol, hydrogen and carbon dioxide. The second group, also Eubacteria, uses the organic compounds (alcohol and acids) from the previous stage to produce acetate, carbon dioxide and hydrogen. The last group of organisms is formed by methanogens of the Archaea domain.

2. A lawn of bacteria is grown on a Petri dish in the incubator. Discs containing different antibiotics are placed at fixed distances. Bacteria grow in all areas of the Petri dish except for the area where the antibiotic has diffused from the disc. If the bacteria are resistant to that antibiotic, they will still grow and there will be no inhibition zone. The diameter of the inhibition zone shows the diffusion of the antibiotic from the disc into the agar.

3. Recombinant DNA can be introduced by direct physical and chemical methods or indirectly by vectors, into whole plants, leaf discs or protoplasts. Once inside the plant, the recombinant DNA is taken up by its chromosome or chloroplast DNA. Marker genes such as those for antibiotic resistance or fluorescence are used to indicate successful uptake of a target gene. The plants that have taken in the gene successfully will be resistant to the antibiotic or will be fluorescent. Through the use of transgenics, one can produce plants with desired traits and increase yields by producing plants that can withstand pests and disease. Improving resistance to diseases and pests reduces the need for herbicides and pesticides. Some transgenic plants have increased tolerance to cold, frost, or drought; all making a crop easier to grow in a constantly changing environment.

4. Oil (petroleum or gasoline) is a hydrocarbon and fossil fuel used as a source of energy. Transport, use and disposal of oil have made it a major pollutant of both terrestrial and marine environments. During accidental spills, action will be taken to remove, remediate or recover the pollutant immediately. Biological remediation can have an edge over the physico-chemical treatment in removing spills as they offer *in situ* biodegradation of oil fractions by microorganisms. Bioremediation is suggested for treating contaminated soil sites because of its low cost and ability to convert contaminants to harmless end products. The bacteria of the genus *Pseudomonas* can use crude oil as an energy and carbon source. Clean-up at oil spills will often involve seeding the spill with *Pseudomonas aeruginosa* and adding nutrients such as urea to accelerate the process.

5. DNA microarrays allow the study of gene expression. Researchers can look at the changing levels of mRNAs in order to see whether genes are turned on or turned off. A DNA microarray is a small matrix that contains a large number of immobilized single-stranded DNA molecules attached to it. This matrix of DNA probes can hybridize with complementary "target" sequences derived from experimental samples to determine the expression level of specific mRNAs in a sample. In a test tube, mRNA molecules are converted to cDNA molecules through reverse transcription. During the synthesis of the cDNA molecules, fluorescent probes are incorporated into these cDNA molecules. The test sample cDNAs receive one colour probe while the control cDNAs carry a different fluorescent colour. These labelled cDNAs then co-hybridize with some of the gene-specific DNA probes on the microarray matrix. They bind to their complementary probes on the microarray by base pairing. Some microarrays directly use mRNA instead of cDNA. Following hybridization and imaging, the ratio of red to green fluorescence for each gene spot on the array reflects that gene's relative expression level in the test compared with a reference sample. Analysis of many samples produces a colorimetric table or heat map of gene expression ratios. The resultant expression profiles provide the researcher or pathologist with a new tool to observe, describe, and understand the molecular variation within tissue specimens. Diagnostic DNA microarrays have been used for genotyping and determination of disease-relevant genes or agents causing diseases, mutation analysis, screening of single nucleotide polymorphisms (SNPs), detection of chromosome abnormalities, and global determination of modification to proteins occurring after translation. Microarray analysis provides information on disease pathology, progression and resistance to treatment, and ultimately may lead to improved early diagnosis and approaches for genetic diseases.

6. Viral vectors are used to insert a healthy gene into a deficient cell. Retroviruses are the most frequently used vectors. These single-stranded RNA viruses enter target cells via specific receptors and make cDNA copies from mature mRNA isolated from cells. Then DNA polymerase synthesizes a complementary DNA (double-stranded). Their DNA is integrated into the genetic material of the cell where it remains for the life of the cell. Integrated genes are also passed on in cell division. Retroviruses are used in gene therapy to cure diseases. They have been tested in treating a condition called severe combined immunodeficiency (SCID). A gene mutation prevents the cells of SCID patients from producing the enzyme ADA; this causes the immune system to work deficiently. Substrates for the enzyme ADA build up in cells and are very toxic to developing lymphocytes. These cells fail to mature and the patient is left without a working immune system. Stem cells from bone marrow or umbilical cord blood are taken out of the body and treated with viral vectors that transfer a normal copy of the ADA gene to them. These cells are returned to the bone marrow where the replacement ADA genes can begin to produce the enzyme.

7. Mutating a gene so it is inactivated can be used to determine its function. This is called knockout technology. Mice can be genetically modified to "knock out" a gene by replacing the functional sequence with a non-functional sequence within stem cells. These stem cells are then fused with an embryo. The resulting mouse is called a chimera. These chimera mice are mated with normal mice and the offspring back-crossed to obtain homozygous knockout mice. By causing a specific gene to be inactive in the mouse, and observing any differences from normal behaviour or physiology, researchers can infer its probable function.

Option C Ecology and conservation

1. **a)** Symbiosis/mutualism.

Note that because it is a "state" question you only need to name the relationship, you do not need to outline it.

b) Producer/first trophic level.

c) Indicator species.

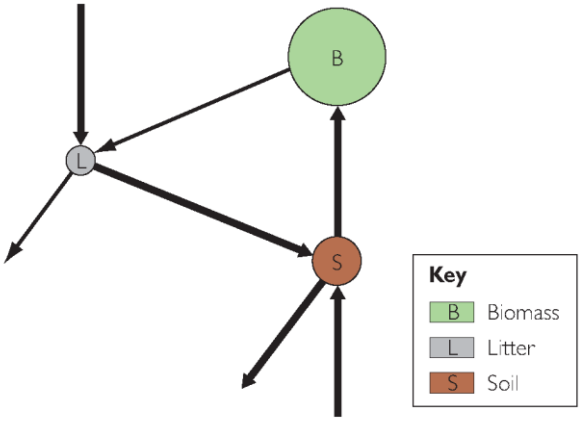
d) Eutrophication is nutrient enrichment of a body of water where the nutrients serve as fertilizer for the algae. When the algae grow, they do not let light in which therefore limits the amount of photosynthesis. At the same time, algae (and other organisms) die and bacteria decompose them using oxygen, therefore increasing the biochemical oxygen demand.

e) Top-down factors refer to, for example, predation which limits population growth. In this case there are herbivores that feed on algae controlling their growth.

2. **a)** Taiga stores nutrients mainly in soil (50%) as litter while a tropical rainforest stores most above the ground (75%) as plant biomass and stores little in soil. In taiga there is a fair amount of nutrients stored above ground. Both have the same percentage of nutrients in roots (around 12 to 15%).

b) The greatest flow of nutrients in taiga is from biomass to litter. The rest of the flows are of similar amounts.

c)



d) In both cases there are tree forests, in taiga evergreen and in the tropical rainforest deciduous. There is a high amount of photosynthesis, increasing biomass above soil.

3. Alien species are those species introduced into a habitat or ecosystem. They can disrupt food chains by reducing the number of organisms that occupy similar niches. Alien species often have no natural predators so may be under little or no control. They can overconsume prey species reducing availability of prey species for other consumers or overconsume a native predator leading to loss of control of the numbers of prey species. Competitive exclusion can lead to a reduction in the numbers of endemic species. Their impact may reduce biodiversity and can lead to the extinction of some species.

4. Edge effects are changes in population or community structures that occur at the boundary of two or more habitats. Areas with small habitat fragments exhibit especially pronounced edge effects that may extend throughout the range. Large areas can support a greater range of habitats and can support longer food chains and higher population numbers. Areas that are larger have fewer disturbed habitats, this means a smaller edge effect. Fragmented areas usually have a greater edge effect. Nevertheless, they can be linked by corridors, allowing for the movement of animals and therefore genetic exchange. The reduced edge effect minimizes the area that is disturbed, as there is less competition. There is a lower edge effect in some geometric shapes than others, for example circular habitats have less edge than rectangular habitats. The island size is also very important to community structure. If the island is small, the community will be more unstable, sometimes leading to extinction of species. The total size of a population on an island with a low area is more likely to be small and low in genetic diversity.

5. The carrying capacity is the maximum population size of the species that the environment can sustain indefinitely. It depends on the availability of water, food, habitat, breeding sites and other available necessities. When a population reaches the carrying capacity of the environment, the population growth slows down. In the sigmoid growth curve, when a population reaches its carrying capacity, the population will stop growing. This is the plateau in the curve. At this point natality and mortality will be equal.

6. In waterlogged soils oxygen is in short supply. This decreases available aeration and favours the process of denitrification by *Pseudomonas.* Insectivorous plants obtain their nutrients but not their energy from consuming animals, especially insects and other arthropods. This is an adaptation to grow in places where the soil is poor in nutrients, for example, in flooded areas such as bogs. Insects are rich in proteins, therefore rich in nitrogen. In this sort of habitat, plants that have alternative strategies for obtaining essential minerals are at a competitive advantage. The capture of insects and other animals thus provides carnivorous plants with a supplemental source of essential nutrients. What truly distinguishes a plant as carnivorous is not only a trapping ability but also a mechanism to digest prey and to absorb the prey's nutrients. There are several trapping methods. Some plants trap insects by rolling their leaves. Others have a sticky substance that acts like flypaper. They have genes involved in making starches and sugars that may help to produce the nectar that lures insects to their deaths, as well as genes encoding waxy substances that may make it hard to escape from the pitcher. Some plants make rapid movements, such as snapping a trap closed.

Option D Human physiology

1. **a)** Potassium.

b) Saturated fatty acids can be deposited inside the arteries. If the deposits combine with cholesterol, they may cause production of an atheroma and lead to atherosclerosis.

c) Hypertension is blood pressure above the norm. The data shows these children have high chances of developing hypertension if they do not change their diet. There is a direct correlation between the amount of sodium in the diet and blood pressure. An atheroma due to deposits of cholesterol can also cause high blood pressure. Potassium helps to decrease blood pressure and here it is lower than recommended.

2. Having food in your mouth will induce the secretion of saliva and the presence of food in the gut will induce the secretion of gastric juice (especially after eating proteins), intestinal juice, pancreatic juice and bile (especially if you have eaten fats). The hormones involved in the chemical control of digestion are gastrin and secretin. These hormones are secreted in the digestive system and travel through blood to the target organs. Gastrin is produced in the stomach by physical stimulation in response to the presence of food as well as to the chemical stimulation by protein. When gastrin is released, it stimulates the production of gastric juice by the gastric glands. Gastric juice changes the pH of the food content from 6.7 to 2, providing acidic conditions that will enhance protein digestion. When there is sufficient gastric juice present, the production of gastrin will stop and therefore so will the secretion of gastric juice. Secretin is produced by special cells in the small intestine in response to the presence of acid. It stimulates the production of alkali by the pancreas, neutralizing the intestinal components. When the pH of the intestine reaches 8, the production of pancreatic juice is stopped. Gastrin and secretin enhance digestion. Somatostatin is an inhibitory hormone secreted by the stomach, duodenum and pancreas. This hormone travels through blood to directly inhibit acid-producing cells. It also acts indirectly by preventing the release of gastrin and secretin, thus reducing the digestive process.

3. Jaundice is caused by the presence of bilirubin in blood and extracellular fluid. It occurs when the bilirubin produced from hemoglobin breakdown in erythrocyte recycling in the liver is not removed from the blood. Bilirubin is hemoglobin with the heme molecule removed. Its level may rise and the skin and whites of eyes may begin to appear jaundiced (yellow). Depending on the level of exposure, the effects range from unnoticeable to severe brain damage and even death. Jaundice appears when there is increased destruction of erythrocytes (as in malaria) or defects in the secretion of bilirubin from hepatocytes due to liver damage such as hepatitis, cirrhosis or liver cancer. It can also be caused by genetic diseases or bile duct obstruction. Cirrhosis can be caused by infection, but in many cases, it is caused by damage from the heavy drinking of alcohol.

4. Cardiac muscle transmits electrical signals as it is myogenic. The SA node initiates the signal which spreads over the atria and reaches the AV node. There is a delay before the signal passes from the AV node to the bundle of His or Purkinje fibres. This delay allows the ventricles to fill as the atria contract. The conducting fibres then spread the signal across ventricle walls for the ventricles to contract.

5. The pancreas is an exocrine gland because it carries away the pancreatic juice containing the digestive enzymes through a duct. It is an endocrine gland because the hormones insulin and glucagon are secreted directly into the blood capillaries.

6. **a)** DPG causes a shift of the saturation curve of hemoglobin. When it is present in high amounts, the saturation curve is shifted to the right. It acts in similar way to low pH levels in blood. When DPG is present in low amounts, the curve is shifted to the left.

b) Organisms living at high altitude are in areas of low oxygen concentrations. They will have a high DPG because it decreases the saturation of hemoglobin. This means that oxygen is more readily released in body tissues by the hemoglobin.

IB Prepared Biology

Answers to practice exam papers

Here are the answers to the practice exam papers from *IB Prepared Biology*.

For direct access, click on the paper below.

Paper 1

Paper 2

Paper 3

Paper 1

1.	C	15.	A	28.	A
2.	C	16.	A	29.	C
3.	A	17.	D	30.	C
4.	B	18.	D	31.	C
5.	C	19.	B	32.	B
6.	B	20.	A	33.	A
7.	D	21.	B	34.	C
8.	A	22.	B	35.	A
9.	A	23.	B	36.	A
10.	D	24.	A	37.	B
11.	D	25.	C	38.	A
12.	D	26.	A	39.	C
13.	A	27.	C	40.	D
14.	A				

Paper 2

SECTION A

1. (a) The strain of *B. thuringiensis* (Bt) that contains the Cry protein that kills the targeted insect must be identified. As a reporter gene, added to the vector is a gene for antibiotic resistance (or a gene for fluorescence). The Bt gene (with the resistance gene attached) is inserted into plant cells. The plants are grown in antibiotic medium to determine which plant cells have successfully received the Bt gene and are now transformed. Any plant cell that has the Bt gene must also have the resistance gene that was attached to it. The modified plants produce the same lethal Bt protein produced by Bt bacteria because the plants now have the gene.

(b) Plant 3

(c) Plant 3 did not transcribe the mRNA for Cry protein. This could be because the gene inserted into the plant was different to the gene for the Cry protein (it was larger). The promoter of the gene is different and due to an insertion, which makes it larger, it is not transcribed.

(d) A large amount of the Cry protein is being produced in the leaves of plants 1 and 2, therefore it can be said that plants 1 and 2 have successfully expressed the gene for the Cry protein. The genetic modification was successful for these two plants only; in plant 3 the genetic modification did not work.

(e) **(i)** Region 1

(ii) Common milkweed is used by monarch butterflies to feed their larvae, so this plant must be present in the butterflies' breeding sites. The greatest percentage of crop that has monarch butterfly breeding sites is in Region 1 (and slightly less in Region 2). So the crops in these sites have greater probability of having Bt corn pollen on them. This region is shown to have the greatest probability of exposure of monarch butterfly to Bt corn pollen, therefore most probably the milkweed has Bt pollen on its leaves.

(f) Bt crops affect butterflies if their pollen grains deposit on the milkweed leaves. The greatest shared area of Bt crops and monarch butterfly breeding sites is low, therefore the chances of these butterflies being affected by Bt corn is low. The average probability of exposure is 0.0011 and the highest (in region 1) is 0.0040. Nevertheless, the long-term exposure has not been studied in this work. The study could have been funded by Bt corn producers.

(g) Monarch butterflies fed on milkweed dusted with pollen from non-Bt corn all survived the 120 h of the experiment. However, those fed on milkweed dusted with pollen from Bt corn showed a decline in their survival. The larvae fed on milkweed dusted with pollen from Bt corn 2 showed a decline after 12 hours but the decline was immediate for those fed on milkweed dusted with pollen from Bt corn 1. After 120 hours, the larvae fed on milkweed dusted with pollen from Bt corn showed a survival proportion of around 0.3–0.4 while the larvae fed on milkweed dusted with pollen from non-Bt corn remained at 1.0.

(h) The graph shows that Bt corn pollen can be lethal for many monarch butterflies, but the table shows that monarch butterflies share a very small breeding area with the Bt crops, therefore the majority of monarch butterflies would not be exposed to the toxin. One should test how far the pollen grains can travel, as they might deposit on milkweed even if the crops are far away. One should study the amounts needed to decrease survival, as perhaps only a few pollen grains could reduce viability.

2. **(a)** Uracil

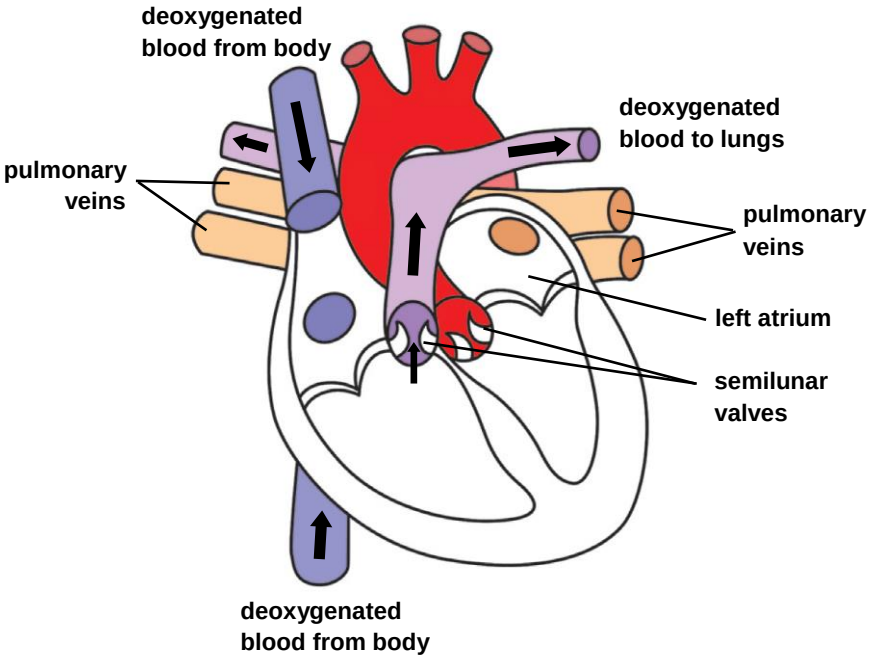
(b) **(i)** In DNA the percentage of adenine and thymine are the same (around 31%) and of guanine and cytosine too (around 18%) while in RNA all nucleotides are found in different percentages.

(ii) The reason for this difference is that DNA forms a double strand of complementary base pairs, therefore C and G that are complementary and A and T that are also complementary must have the same values. In RNA, as they are single strands, the amounts of each nucleotide are variable.

(c) DNA can be found in the nucleus of the cell. The mRNA can be found in the nucleus, in the cytoplasm, attached to ribosomes and in RER. In the mitochondria and chloroplasts both DNA and mRNA can be found.

3. **(a)** Pulmonary vein, left atrium and semilunar valve correctly labelled, as shown below.

(b) One mark for annotation showing deoxygenated blood from body to right atrium and one mark from right ventricle to pulmonary arteries out to lungs (only one side needs to be labelled).



(c) The ventricles contract during the heart systole. The left ventricle has a thicker wall than the right ventricle. Blood in the right ventricle needs to travel from the heart to the lungs, which are close to the heart. The left ventricle pumps blood to the rest of the body. This requires a greater pressure to ensure blood reaches areas far away from the heart.

4. A: Filicinophyta
B: Coniferophyta
C: Angiospermophyta
D: Bryophyta

5. **(a)** Any **two** from: Double membrane; 70S ribosomes; own DNA.

(b) Chemiosmosis is the movement of ions across a partially permeable membrane, down their electrochemical gradient. In the mitochondria, chemiosmosis occurs when protons diffuse through ATP synthase to generate ATP. The energy to maintain the hydrogen gradient comes from the redox reactions of the electron transfer chain. Protons are pumped out of the membrane into the intermembrane space where they build up. When they come back through the ATP synthase enzyme they cause the phosphorylation of ATP (transforming ADP into ATP).

SECTION B

6./8. **(a)** Drawing of chloroplast showing the following and labelled:

- double membrane shown with straight lines (not hatched) labelled inner and outer
- thylakoid membranes stacked as grana
- stroma
- starch granules as roundish dots smaller than grana
- DNA as circle
- small/70S ribosomes as dots smaller than starch granules.

(b) In the light-dependent reactions, absorption of light by photosystems occurs. Photolysis of water generates excited electrons. These electrons are carried through an electron carrier chain. Reduced NADP and ATP are produced in the light-dependent reactions which are required for the light-independent reactions. The light-independent reactions occur in the stroma of the chloroplast. A carboxylase catalyses the carboxylation of ribulose bisphosphate (a 5 C sugar). In a carboxylation, carbon dioxide is added to the molecule. The 6C sugar formed is broken into two 3C molecules. Glycerate 3-phosphate (3C) is reduced to triose phosphate (3C) using reduced NADP and ATP. Triose phosphate is used to regenerate ribulose bisphosphate and produce carbohydrates, such as starch, using ATP.

(c) The starch is digested with salivary amylase, which breaks down some of the starch into maltose (and shorter amylose chains or dextrins). The food is then taken to the stomach and from there to the small intestine. The pancreatic amylase, secreted into the lumen of the small intestine, continues the digestion of starch into maltose. Maltose is then digested by maltase into glucose molecules (monomers).

7./9. **(a)** Anaerobic respiration occurs without the use of oxygen. In some bacteria, during anaerobic respiration, lactose is converted to lactic acid (lactate). This reaction occurs in the production of yoghurt from milk. Other lactic acid fermentation of foods includes pickling, and the production of kimchi and sauerkraut. In other bacteria or yeast, glucose is converted to ethanol and carbon dioxide. This type of fermentation is used in the production of bread, spirits or wine. Both these reactions yield a small amount of ATP (2 molecules per molecule of glucose).

(b) Resistance to an antibiotic can be acquired by mutation or by conjugation. The gene responsible for resistance is usually on a plasmid. If antibiotics are used, bacteria that are not resistant will be killed, but those that are resistant will not only survive, but will have no, or less, competition. In this way the resistant bacteria will reproduce and pass on the resistance to their offspring. They will also pass it to further bacteria by conjugation. By natural selection, the resistant bacteria survive and thrive in the environment. This is evolution by natural selection.

(c) The immune system activates a series of mechanisms to defend the body against a bacterial infection. Phagocytes engulf the bacteria giving non-specific immunity. Production of antibodies by lymphocytes in response to particular antigens on the bacterial wall gives specific immunity. Antibodies are proteins that can attach to pathogens destroying them or flagging them for other leucocytes to phagocytose them. Some lymphocytes mature to become antibody-producing cells called plasma cells (or B cells). Memory cells are a clone of plasma cells that remember how to produce specific antibodies, therefore are very useful if there is a second encounter with the same type of bacterium.

10. **(a)** The Malpighian tubules are a series of branched tubes that reach the alimentary canals in most arthropods. Instead, in vertebrates, the kidneys are more complex organs composed of many nephrons in the cortex and medulla joining into the collecting ducts that lead to the ureter in the pyramid. Each nephron consists of a Bowman's capsule that contains a glomerulus which is a blood capillary. Absorption of useful substances and excretion of wastes is much simpler in the Malpighian tubules than in the kidneys. In the Malpighian tubules, the water and wastes from the body fluids are absorbed by diffusion and mineral ions by active transport. These substances are released from the Malpighian tubules into the alimentary canal. Mineral ions are reabsorbed by the rectum by active transport and water is reabsorbed by osmosis. The wastes are excreted as nitrogenous wastes together with undigested food. In the kidneys, specifically in each nephron, blood carrying useful substances and wastes enters through a high-pressure capillary called a glomerulus causing ultrafiltration in the Bowman´s capsule. This glomerular filtrate collects and passes to the proximal convoluted tubule that selectively reabsorbs useful substances by active transport.

It contains many mitochondria and microvilli for absorption. The loop of Henle maintains hypertonic conditions in the medulla. The descending loop is permeable to water but not to ions and the ascending loop is permeable to ions but not to water. This structure produces a high concentration of salt ions in the medulla. The filtrate then moves to the distal convoluted tubule, where more useful substances are reabsorbed. Next, in the collecting duct, water is reabsorbed and urine carried to the bladder through the ureters for excretion.

(b) The reabsorption of water is controlled by anti-diuretic hormone, ADH. This peptide hormone is produced by the hypothalamus and stored in the (posterior) pituitary gland. It is released when the body requires water, for example during hot days. This hormone promotes the reabsorption of water in the distal convoluted tubule and collecting ducts.

(c) Drawing of elbow joint showing the following labelled structures:

- humerus, radius and ulna
- capsule with synovial fluid
- cartilage surrounding the ends of bones
- ligaments joining bones.

Paper 3

SECTION A

1. (a) Food 1: 0% (any value close to 0% lower than 0.05%).
Food 2: 1% (any value close to 1%, such as 0.8% or 1.2% is accepted).

(b) This is not a precise method, as it can be seen that at 0.3% the test tube looks darker than at 1% glucose.
(The problem is that Benedict's solution is blue, so when mixed with yellow-orange it gives a green solution that could confuse the naked eye.)

(c) To obtain the 1% glucose concentration you weigh 1 gram of glucose and place it in 100 g (or ml) of water. To obtain the 0.1% glucose solution, you could weigh 0.1 grams of glucose and add 100 g water, but it is easier just to take 1 ml of the 1% solution and add 9 ml of water to dilute it 1:10.

2. (a) Any **one** method from:

- Lamps could be placed at different measured distances;
- Use a lamp that emits different light intensities, keeping at the same distance;
- Place filters in front of the lamp to diminish light intensity.

(b) It is important to keep temperature as a fixed value, not another variable. This will make measurements consistent. As lamps give off heat, the water bath might change temperature. To keep the temperature constant, cold water or ice can be added.

(c) The capillary tube and plastic tubing must be filled with water at the start of the experiment. As the pond weed photosynthesizes, oxygen bubbles are produced. These bubbles collect in the funnel end of capillary tube above the plant. The oxygen can then be drawn up the capillary tube by gently withdrawing the syringe. The length of the column of oxygen collected is recorded on the scale (in mm), and the volume of gas can be calculated as the internal radius of the tube is known. It is important to record the time, as rate is measured in volume per unit of time.

3. DNA has a negative charge due to the phosphate in the sugar–phosphate backbone. DNA is placed in the well of the gel. The gel is placed in a chamber containing a buffer and an electrical potential difference is applied. DNA (that has usually been cut by enzymes producing fragments of different sizes) moves towards the anode that has a positive charge. Larger fragments migrate more slowly because of the resistance offered by the gel. Therefore smaller fragments will be closer to the anode.

SECTION B

Option A

4. (a) Neurons are produced by differentiation in the neural tube. Immature neurons start growing dendrites. Immature neurons migrate to a final location and grow an axon. Multiple synapses are formed with other neurons.

(b) Infolding of the ectoderm forms the neural plate. The cells in the neural plate make a groove. This groove elongates into a tube.

(c) Pruning

5. There is a positive correlation between body mass and brain mass, the larger the organism the larger the brain. Nevertheless, there are exceptions to this rule. The data shows there is a positive relationship between brain mass and longevity; therefore, it supports the hypothesis that at a higher body mass there is a greater longevity.

6. (a) (i) II

(ii) III

(iii) I

(b) Light rays shown entering through pupil to retina.

(c) Hairs of the cochlea detect sound, so are involved in hearing, while hairs in the semi-circular canals detect movement and are involved in monitoring posture.

7.

- The autonomic nervous system controls involuntary processes using centres in the medulla oblongata.
- The autonomic nervous system has two parts: parasympathetic and sympathetic.
- They have contrary or complementary effects on an involuntary process, where one accelerates a process the other slows it down.
- For example, during digestion the parasympathetic system increases intestinal peristalsis while the sympathetic system acts when no digestion is required and therefore slows down peristalsis.

8. 1: white matter, 2: grey matter, 3: motor neuron, 4: sensory neuron

9. Innate characteristics should be the same (or nearly the same) in control and isolated passerines. The number of songs is very different, so birdsongs are probably not innate. The song lengths are similar, so possibly are innate. This means the hypothesis not supported for all song characteristics.

10.

- Cocaine is an excitatory drug.
- It is a strong stimulant which increases alertness and talkativeness. It causes euphoria and an exaggerated sense of confidence.
- People taking cocaine have a sensation of force and power thus displaying reckless behaviour.
- They also have a sense of anxiety, might hallucinate or have panic resulting in dangerous behaviour. They experience bad judgement so have quick changes of perception and reckless driving.
- When the effect is over they may feel tired so become suicidal.
- Fatigue and depression cause psychological dependency or addiction.

Option B

11. (a) Any **two** from: conditions that need to be controlled are temperature, nutrients (for example glucose), pH, oxygen levels, foam and carbon dioxide.

(b) Any **one** from: paddles help to mix the substrate with the fungus. The movement of the paddles allows for aeration.

12. (a) Flavouring / preservative

(b) 100% bagasse in a fermenter.
Note that the percentage and the type of fermentation are both needed for the mark.

(c) Tray fermentation gives slightly less yield than in a fermenter. The exception is at 75% bagasse in 6 cm trays, where the yield is the same. Fermentation in trays of 2 cm depth is not the best, as the yield is always the lowest. Considering that trays are much cheaper than fermenters, it is a solution to do the fermentation in 6 cm trays.

13. (a) Gram staining is used to detect Gram-positive bacteria. A smear is heated and stained with crystal violet and iodine. Rinsed with alcohol and counterstained with safranin. Gram-positive are blue-violet (while Gram-negative are pink).

(b) Bacteria reproduce and grow (most probably between weeks 1 and 2). The exopolysaccharide grows in thickness (most probably during weeks 2 and 3).

(c) 45% (as the lines are not precise, a range of values is accepted between 42% and 47%).

(d) During the first weeks, the change in viability is not much. The biofilm makes an EPS (exopolysaccharide) matrix which protects the bacteria from the antibiotic. In week 3, the viability increases a lot. Cells divide less, so antibiotics have less chance of acting on them and the EPS is thick so fewer antibiotics enter.

14.

- A plasmid containing the gene for resistance (for example to glyphosate) and a reporter gene (such as a gene for antibiotic resistance) is constructed.
- The reporter gene is used to confirm target gene uptake.
- This plasmid has a eukaryotic promoter upstream of the target gene to initiate replication once in the host plant.
- The plasmid is incorporated into the plant either by infection (Ti plasmid) or using chemical or physical means. Once the plasmid is in the plant cell, the DNA becomes incorporated into the DNA of the plant.

15. (a) Pig

(b) Any amino acid that has a dash all the way down.

(c) Blast p search in NCBI or any other database. Sequences aligned with Clustal W (or any other software).

16. Viral vectors are used to replace defective genes. The first step is to identify and isolate the normal allele of the specific gene. The normal gene is then inserted into the virus. The virus is modified so it does not cause disease, but can still enter the cell. Retroviruses are often used as vectors. The next step is to isolate white blood cells from the bone marrow cells or stem cells from the placenta. The modified virus is mixed with the isolated body cells. The virus makes the normal gene to be inserted into the chromosomes of the cells. An example of genetic modification using viral vectors is in severe combined immunodeficiency (SCID), a genetic disorder. The viral vector is used to replace the gene to produce the enzyme adenosine deaminase (ADA) which is defective in the SCID patients.
If an adenovirus is used instead of a retrovirus, the gene is not incorporated into the genome; therefore, the treatment needs to be repeated many times, as the gene is not replicated.

This question is worth 6 marks, so it is important that you at least write about 6 points. Marks are for:

- named viral vector (e.g. retrovirus)
- modification of virus so it is not infective
- isolation of white blood cells
- named disease (e.g. SCID)
- named gene (e.g. ADA)
- incorporation into DNA

Option C

17. (a) Small: 115
Medium: 90
Large: 39 (a range plus or minus 2 is accepted for all values).

(b) Numbers of colonies decreased in small and medium colonies. Small colonies decreased the most, while medium colonies decreased then remained constant. Large colonies had lower numbers and remained (relatively) constant.

(c) Any **one** from:

- The number of corals could have been reduced by humans removing corals as souvenirs.
- Corals could have been preyed upon by natural predators (or alien species).
- Corals could have died due to pollution or warm temperatures.

(d) Bleaching is the removal of the symbiotic zooxanthellae from corals. This could be due to lack of nutrients, warm temperatures, eutrophication or pollution. The greater the bleaching, the higher the probability the corals have suffered stress.

18. (a) The population density of the bacterium *S. marcescens* increases exponentially at high nutrient level compared to low nutrient level (from 1,000 to 100,000).

(b) When one trophic level is added (microcosm 2), the *P. aurelia* feed on the *S. marcescens*, lowering their density. When *D. nasutum* is added (microcosm 3), this organism predates on *P. aurelia*, lowering their numbers and at the same time decreasing the predation on *S. marcescens*, which increase in density.

(c) At low nutrient levels there are few *S. marcescens,* this means that the predation by the second and third trophic levels is not enough to lower the density of *S. marcescens.* There is not enough energy to maintain the food chain.

(d) The length of chains in webs is probably much shorter at low nutrient levels, as energy is lost between each link.

19. (a) D = 90/36 = 2.5

(b) This community has only three species, so its richness is low. The number of organisms in each species is different, so the evenness is also low.

(c) The forest has a greater biodiversity, as it has a larger Simpson diversity index. The richness is greater in the forest, but the evenness cannot be compared, as there is not enough information about the distribution of number of the species studied in the forest.

20.

- Biological pest control is the introduction of a predator to limit a pest species.
- The organism used as biological pest control may damage the ecosystem because they may not have natural predators they may get out of control.
- The biological pest control may alter food webs or cause allergies. They are usually introduced when there is a pest infestation, when it is too late.
- There are ethical concerns about introducing biological controls to change the natural ecosystems.

21. (a) The amount of nitrogen-containing ions in soil will affect the nitrogen in leaves. If the number of nitrogen-fixing bacteria or *Rhizobium* is larger there will be more nitrogen. At higher numbers of denitrifying bacteria in soil (especially if there is a lack of oxygen) the amount of nitrogen in the soil will be reduced.

(b) City size does not make a significant difference to the nitrogen concentration in *Q. robur* leaves, although larger cities have a slightly larger concentration (not significant). In all cases urbanization increased the concentration of nitrogen slightly but not significantly.

22.

- Bottom-up limiting factors affect from a lower trophic level or a nutrient store. In a pond they include nutrient availability, food and habitat.
- If nutrients are rich in the pond, algae grow. This means that there are many producers that serve as food.
- Eventually the growth can cause eutrophication. This will determine the death of many organisms. Shortage of nutrients controls algal blooms. Lack of food or space will determine the slow growth of organisms.
- Top-down control is by herbivory or predation.
- The herbivores present in the pond will feed on algae and plants, maintaining their numbers. If the herbivores are present in excess, the producers will be reduced.
- If the predators of the herbivores are in excess, the plants will be able to grow a lot.

Option D

23. (a) As the level of phenylalanine increases, brain function decreases. It is an inverse relationship or a negative correlation.

(b)

- Phenylalanine is an essential amino acid. The inability to convert phenylalanine into tyrosine will cause phenylalanine to increase in blood and tyrosine to be lacking.
- Tyrosine therefore becomes an essential amino acid for PKU patients. This requires a lifelong controlled diet rich in tyrosine and low in phenylalanine, not a diet without proteins.
- A protein-restricted diet may create problems of protein deficiency, such as lack of energy, poor muscle growth, weak hair and others. Obviously, there will be lack of essential amino acids; that is why supplements are also needed. It is also a risk to the developing fetus in pregnant PKU mothers.

24. (a)

- The data shows that as inhibition increases, the hepatic extraction rate decreases.
- This is because the liver is not capable of detoxifying the drug and therefore it will remain in blood plasma, increasing its concentration. If all the enzymes are inhibited, there is no extraction, leading to the accumulation of the drug in the liver.
- This supports the hypothesis that drug competitive inhibitors can reduce the hepatic extraction ratio and this could eventually permanently damage the liver. Nevertheless, there is no real information of liver damage in the data supplied.

In a discussion you must look at pros and cons. In this case, just saying that the hypothesis is supported is not enough. Just saying that there is not enough data to support the hypothesis is not enough either.

(b) Any **two** from: Storage of nutrients (glycogen, proteins, iron); breakdown of red blood cells; storage of vitamins/minerals; warming of blood; bile production; metabolism of carbohydrates/fats; synthesis of plasma proteins; synthesis of angiotensin.

25. (a) Hypertension is pressure above normal. In humans normal blood pressure is around 70 mm Hg during diastole and 120 mm Hg during systole.

Note that blood pressure during diastole and systole are both are needed for the mark.

(b) Exercise reduced the resting heart rate from 78 to 76.5 bpm (a 2.5% reduction). The error bars do not overlap, so we can say the difference is significant.

Because this question is worth 2 marks, two points must be made. It is always important to check whether any differences are significant.

(c) Heart rate is similar to pulse, thus measured the same way. An artery is pressed against and measured for 1 minute (or a fraction of a minute and multiplied to obtain a minute). Usually it is measured in the wrist, inside the elbow, side of the neck or top of the foot.

(d) Cardiac muscle cells are muscle cells with one nucleus and joined end-to-end in a network by intercalated discs. The intercalated discs have gap junctions that allow rapid movement of ions between cells. Depolarization can thus pass quickly from one cell to the other. They are formed by sarcomeres with contractile proteins actin and myosin.

For the two marks, the important points are:
- presence of intercalated discs with gap junctions
- they are joined together forming fibres.

26. The nervous system control of digestion is mainly by the autonomic nervous system. The parasympathetic system accelerates digestive processes such as peristalsis. The presence of food (or its smell) is detected and messages are sent to the medulla in the brain. The appetite control centre in the hypothalamus is stimulated. Messages are sent through the vagus nerve to the stomach. Glands in the stomach secrete gastric juice. When food reaches the stomach, chemoreceptors and stretch receptors send impulses to the brain to cause further secretion of gastric juices and enzymes.

The four marks are for the following:
- parasympathetic system controls peristalsis
- controlled in medulla
- vagus nerve
- chemoreceptors and mechanoreceptors.

27.
- Binding of the growth hormone rotates the receptor molecule subunits, changing the alignment of the intracellular part of the receptor.
- This activates a cascade mediated by a second messenger inside the cell.
- The second messenger activates an enzyme which initiates a number of changes which activate genes.
- The process requires energy in the form of ATP.

28.

Fetal hemoglobin and adult hemoglobin are similar in structure, but not identical. Fetal hemoglobin transports oxygen from the umbilical vein to the rest of the fetus during the 7 months before birth. Adult hemoglobin transports oxygen from the lungs to the rest of the body. Fetal hemoglobin is different to the adult hemoglobin because it can bind oxygen with more affinity, therefore extracting the oxygen from the mother's blood in the placenta. The greater affinity is determined by a difference in one single amino acid, serine instead of histidine. (Serine does not interact with 2,3-BPG that decreases affinity of hemoglobin for oxygen.) The difference in affinity can be seen in the oxygen saturation curve; the fetal haemoglobin curve is shifted to the left with respect to adult hemoglobin. This means that it becomes saturated with oxygen at a lower partial pressure of oxygen.

In order to score 6 marks the following is necessary:

- function of each hemoglobin
- greater affinity of fetal hemoglobin for oxygen
- need for greater affinity of fetal hemoglobin
- how this affinity is obtained
- effect on saturation curve (shift to left) (can be shown as a drawing)
- effect of partial pressure on saturation.